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SUBJECT: VARIABILITY IN DAYTIME STABILITY CLASS DESIGNATION UNDER PARTLY FOGGY CONDITIONS IN A MONITORING STUDY

ABSTRACT

A monitoring study conducted in August of 2004 along the Northern California coast (Wofford et al. 2005) provided an opportunity to compare two different methods for determining daytime stability classes for modeling. The 'conventional' method utilized field notes to determine foggy periods and assigned these hours D stability. The remaining daytime hours were assigned Pasquill-Gifford stabilities in accordance with procedures that rely on estimating the sun angle and satisfying the requirement of no more than one stability class change per hour (Johnson et al. 1999). The 'solar radiation' method utilized solar radiation measurements and wind speed to determine daytime hour stability (U.S. EPA 2000). Both the conventional and solar radiation methods gave similar results. The differences in stability class were well within U.S. EPA guidelines. The resulting differences in flux calculations over daytime flux intervals averaged 9.3 percent (± 11.1 standard deviation).

INTRODUCTION

It is common along the northern coast to have foggy nights and mornings with clearing during the day. In a monitoring study of the joint application of 1,3-dichloropropene (1,3-d) and metam sodium (Wofford et al. 2005) field notes were taken to indicate times of sunny conditions and times of foggy conditions. Times were not exact but within an hour. The meteorological station measured wind speed at ten meters height and solar radiation. DPR conventionally determines daytime stability classes utilizing wind speed and sun angle in accordance with Table 1 (Johnson et al. 1999). The sun angle is classified crudely into high, moderate, and slight solar radiation. This method will be called 'conventional.' However, the availability of solar radiation measurements in Wofford et al., (2005) enabled use of the solar radiation Delta-T methodology (U.S. EPA 2000). The Delta-T part of the title refers to determining nighttime stability and was not employed here. Solar radiation levels are classified into four categories and together with wind speed are used to determine stability (Table 2). This will be called the 'solar radiation' method.

There were 18 monitoring intervals, which consisted of 4 to 12 hour periods. Nine of these were daytime intervals. The concentrations measured during the study were modeled with the industrial source complex short term (ISCST3) model (U.S. EPA 1995) using the two methods for determining stability classes. These concentration estimates were then compared to the measured values to back calculate flux for each interval (Johnson et al. 1999).

A stability class was assigned to each hour of the monitoring study using both the conventional method and the solar radiation method. Since there were no Delta-T measurements, the stability classes assigned to nighttime periods were the same. Of the nine daytime sampling intervals, there were eight intervals during which one or more hours differed in the stability class estimation (Table 3).

RESULTS

Stability class differences

Table 4 accounts for the differences between the two methods for estimating daytime stability classes. A count of the differences fall within U.S. EPA guidelines, which state that the solar radiation (and Delta-T) method give the same results as the Turner method about 60 percent of the time and are within one stability class about 90 percent of the time (U.S. EPA 2000). Table 4 indicates that the two methods as employed here were within one stability class 99 percent of the time. In addition, in 14 of 27 cases, which differed by one stability class, the conventional method estimated greater stability and in the remaining 13 of 27 cases it estimated less. Thus there appeared to be no consistent bias in differences between the two methods.

Difference in individual interval flux rates

The regressions for sampling intervals 1 and 15 were not statistically significant. The concentrations and model-predicted values were each sorted from lowest to highest and regression analysis was redone. This procedure improved the r^2 values. For technical reasons, the conventional p values are not appropriate for sorted data and will not be reported. For the eight sampling intervals which were compared using both methods, the relative differences in flux (Tables 5 and 6) were under 20 percent, except for intervals 1 and 17 with a relative percent difference of 23.5 and 29.1 for methyl isothiocyanate (MITC), respectively, and 23.2 and 34.6 for 1,3-d, respectively. The average difference (averaging over periods) between flux calculations based on the conventional versus solar radiation approaches was 10.7 percent and 9.5 percent for MITC and 1,3-d, respectively.

To put the percent difference in context with the overall variation that occurs when calculating flux estimates, we can look at the confidence limits around the flux calculations. Table 7 lists the upper and lower 95 percent confidence limits for the flux estimates for each interval. The percent average difference was calculated for each interval and the overall mean and standard deviation for each chemical was determined. The average difference for MITC (+/- 1 sd) and 1,3-d (+/- 1 sd) was 63 percent ± 34 and 66 percent ±35, respectively.

In comparison the average differences between flux calculations based on the method used to establish stability classes for both MITC and 1,3-d were approximately six times less. Therefore, the method of determining stability classes has a smaller influence on the final estimates than the general variability involved in the calculations.

Sensitivity of mass loss alternative schemes of analysis
Table 8 lists the daily 24-hour Time-Weighted Average (TWA) flux for each method of stability class determination. A paired T-test on daytime fluxes found that the difference in flux results between the two methods for determining stability class was not significant for either MITC or 1,3-d. Figure 1 shows the plots of the 24-hour TWA flux rates for the two different stability class methods. In addition, the plots of the highest 24-hour TWA measured concentration found at any sampler location and the average 24-hour TWA measured concentration for all the sampler locations were added to the graph. For both chemicals the flux and concentration curves are parallel. It is interesting that while MITC flux declined; flux for 1,3-d increased over the six-day period.

Emission, as a percent of applied material, during the nine daytime sampling intervals are listed in Table 9. The total daytime emissions for MITC using the solar radiation method were seven percent higher than the conventional method. For 1,3-d, the total emission based on the solar radiation method yielded an estimate two percent below the corresponding estimate based on the conventional method.

CONCLUSION

Two criteria were used to determine hourly daytime stability classes in conjunction with an MITC and 1,3-d monitoring study. These were called the conventional method and solar radiation method. Differences in individual hourly stability classes were within U.S. EPA guidelines for these kinds of methods. In addition, subsequent calculations based on the two different daytime stability class determinations showed statistically non-significant differences between interval-calculated fluxes. The average percent difference between flux calculations based on theses two methods was 9 percent for MITC and 9.5 percent for 1,3-d. These differences are relatively minor.

cc: Randy Segawa
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Table 1. Tables from Johnson at al (1999) showing the Pasquill stability class determination based on wind speed, night/day, and solar insolation. The second table indicates how to convert information on cloud cover into solar insolation categories.

Surface Wind Speed at a Height of 10 m (m/sec)	Day			Night	
	Incoming Solar Radiation* (Insolation)			Thinly Overcast or ≥ 4/8 Low Cloud Cover	≤ 3/8 Cloud Cover
	Strong	Moderate	Slight		
< 2	A	A – B	B	F	F
2 – 3	A – B	B	C	E	F
3 – 5	B	B – C	C	D	E
5 – 6	C	C – D	D	D	D
> 6	C	D	D	C	D

The neutral class (D) should be assumed for all overcast conditions during day or night.

*Appropriate insolation categories may be determined through the use of sky cover and solar elevation information as follows:

Sky Cover	Solar Elevation Angle > 60º	Solar Elevation Angle ≤ 60º but > 35º	Solar Elevation Angle ≤ 35º but > 15º
4/8 or Less or Any Amount of High Thin Clouds	Strong	Moderate	Slight
5/8 to 7/8 Middle Clouds (7000 feet to 16,000 foot base)	Moderate	Slight	Slight
5/8 to 7/8 Low Clouds (less than 7000 foot base)	Slight	Slight	Slight

Table 2. Key to Solar Radiation Delta-T (SRDT) method for estimating Pasquill-Gifford (P-G) Stability Categories (U.S. EPA 2000).

Daytime				
Wind Speed (m/s)	Solar Radiation (W/m^2)			
	≥ 925	925 - 675	675 - 175	< 175
< 2	A	A	B	D
2 – 3	A	B	C	D
3 – 5	B	B	C	D
5 – 6	C	C	D	D
≥ 6	C	D	D	D

Nighttime		
Wind Speed (m/s)	Vertical Temperature Gradient	
	< 0	≥ 0
< 2.0	E	F
2.0 – 2.5	D	E
≥ 2.5	D	D

Table 3. The stability classes used for modeling the application monitored.

			Stability Class						Stability Class	
Sampling Interval	Date	Start Time	Conventional	Solar radiation		Sampling Interval	Date	Start Time	Conventional	Solar radiation
1	7/21/04	7:40	3	3		13	7/24/04	7:40	4	4
		8:40	4	3				8:40	4	4
		9:40	4	3				9:40	4	3
		10:40	3	2				10:40	3	2
2	7/21/04	11:40	2	1				11:40	2	3
		12:40	2	2				12:40	1	3
		13:40	1	1				13:40	2	3
		14:40	2	2				14:40	2	3
3	7/21/04	15:40	2	2				15:40	2	3
		16:40	3	3				16:40	3	3
		17:40	3	3				17:40	3	4
		18:40	4	4				18:40	4	4
4	7/21/04	19:40	5	5		14	7/24/04	19:40	4	4
		20:40	6	6				20:40	4	4
		21:40	6	6				21:40	4	4
		22:40	6	6				22:40	4	4
5	7/21/04	23:40	5	5				23:40	4	4
		0:40	6	6				0:40	4	4
		1:40	6	6				1:40	4	4
		2:40	6	6				2:40	4	4
6	7/22/04	3:40	6	6				3:40	4	4
		4:40	6	6				4:40	4	4
		5:40	6	6				5:40	4	4
		6:40	6	6				6:40	4	4
7	7/22/04	7:40	5	5		15	7/25/04	7:40	4	4
		8:40	4	4				8:40	4	3
		9:40	3	3				9:40	3	3
		10:40	2	2				10:40	2	3
		11:40	2	1				11:40	2	2
		12:40	2	1				12:40	2	2
8	7/22/04	13:40	2	1				13:40	2	2
		14:40	2	2				14:40	3	2
		15:40	2	2				15:40	3	2
		16:40	3	3				16:40	3	3
		17:40	3	3				17:40	3	3
		18:40	4	4				18:40	4	4
9	7/22/04	19:40	5	5		16	7/25/04	19:40	4	4
		20:40	5	5				20:40	4	4
		21:40	5	5				21:40	4	4
		22:40	4	4				22:40	4	4
		23:40	4	4				23:40	4	4
		0:40	4	4				0:40	4	4
10	7/22/04	1:40	4	4				1:40	4	4
		2:40	4	4				2:40	4	4

			Stability Class						Stability Class	
Sampling Interval	Date	Start Time	Conventional	Solar radiation		Sampling Interval	Date	Start Time	Conventional	Solar radiation
		3:40	4	4				3:40	4	4
		4:40	4	4				4:40	4	4
		5:40	4	4				5:40	4	4
		6:40	4	4				6:40	4	4
11	7/23/04	7:40	4	4		17	7/26/04	7:40	3	4
		8:40	4	4				8:40	2	3
		9:40	4	3				9:40	2	2
		10:40	3	3				10:40	2	3
		11:40	2	2				11:40	2	2
		12:40	2	1				12:40	2	2
		13:40	2	2				13:40	2	2
		14:40	2	2				14:40	2	2
		15:40	2	3				15:40	2	2
		16:40	3	3				16:40	2	3
		17:40	3	3				17:40	2	3
		18:40	4	4				18:40	3	4
12	7/23/04	19:40	4	4		18	7/26/04	19:40	4	4
		20:40	4	4				20:40	4	4
		21:40	4	4				21:40	4	4
		22:40	4	4				22:40	4	4
		23:40	4	4				23:40	4	4
		0:40	4	4				0:40	4	4
		1:40	4	4				1:40	4	4
		2:40	4	4				2:40	4	4
		3:40	4	4				3:40	4	4
		4:40	4	4				4:40	4	4
		5:40	4	4				5:40	4	4
		6:40	4	4				6:40	4	4

Table 4. Breakdown of stability class estimate differences.

Estimates	Count	Percent
Agree	44	61
Differ by 1 class	27	38
Differ by 2 classes	1	1
Total	72	100

Table 5. Results of regressions for MITC.

Sampling interval	Conventional method			Solar radiation measurements			Percent Difference[1]
	r^2	p-value	Flux ($ug/m^2/sec$)	r^2	p-value	Flux ($ug/m^2/sec$)	
1	0.47*	**	18.31	0.43*	**	23.18	23.5
2	0.91	<0.001	49.37	0.90	<0.001	53.83	8.7
3	0.50	0.002	25.03	0.50	0.002	25.03	0.0
7	0.39	0.010	5.230	0.36	0.013	5.230	0.0
8	0.88	<0.001	6.741	0.88	<0.001	6.972	3.4
11	0.72	<0.001	4.182	0.70	<0.001	4.274	2.2
13	0.77	<0.001	1.374	0.77	<0.001	1.347	2.0
15	0.81*	**	1.270	0.82*	**	1.441	12.6
17	0.86	<0.001	0.7698	0.80	<0.001	0.5742	29.1
						Average	9.0
						Std deviation	±10.7

[1] percent Difference = $\frac{|C1-C2|}{(C1+C2)/2} * 100$

* Concentrations were sorted before regression analysis.
**p value cannot be calculated using conventional statistics.

Table 6. Results of regressions for 1,3-d.

Sampling Interval	Using field notes			Using solar radiation measurements			Percent Difference[1]
	r^2	p-value	Flux ($ug/m^2/sec$)	r^2	p-value	Flux ($ug/m^2/sec$)	
1	0.48*	**	1.772	0.43*	**	2.236	23.2
2	0.49	0.003	5.320	0.47	0.003	5.701	6.9
3	0.94*	<0.001	1.144	0.94*	<0.001	1.144	0.0
7	0.56	<0.001	0.8435	0.54	0.001	0.8505	0.8
8	0.92	<0.001	2.612	0.92	<0.001	2.697	3.2
11	0.77	<0.001	5.946	0.76	<0.001	6.108	2.7
13	0.80	<0.001	5.117	0.82	<0.001	5.079	0.7
15	0.74*	**	7.780	0.76*	**	8.909	13.5
17	0.72	<0.001	7.208	0.59	<0.001	5.081	34.6
						Average	9.5
						Std deviation	±12.3

[1] percent Difference = $\frac{|C1-C2|}{(C1+C2)/2} * 100$

* Concentrations were sorted before regression analysis.
**p value cannot be calculated using conventional statistics.

Table 7. Percent difference in 95 percent limits around flux estimate.

	Sampling Interval	r^2	p-value	Flux ($ug/m^2/sec$)	95 percent Upper Limit	95 percent Upper Limit	Percent Difference[1]
MITC	1	0.47*	**	18.31	0.0673	0.2989	127
	2	0.91	<0.001	49.37	0.4038	0.5836	36
	3	0.50	0.002	25.03	0.1065	0.3941	115
	4	0.87*	**	11.46	0.0894	0.1397	44
	5	0.70	<0.001	12.31	0.0769	0.1694	75
	6	0.94	<0.001	15.78	0.1340	0.1815	30
	7	0.39	0.010	5.230	0.0147	0.0899	144
	8	0.88	<0.001	6.741	0.0532	0.0816	42
	9	0.78	<0.001	2.289	0.0159	0.0299	61
	10	0.95	<0.001	2.320	0.0201	0.0263	27
	11	0.72	<0.001	4.182	0.0267	0.0569	72
	12	0.72	<0.001	0.926	0.0059	0.0126	71
	13	0.77	<0.001	1.374	0.0094	0.0181	63
	14	0.91	<0.001	1.417	0.0115	0.0168	37
	15	0.81*	**	1.270	0.0092	0.0162	55
	16	0.84	<0.001	1.483	0.0111	0.0185	50
	17	0.86	<0.001	0.7698	0.0059	0.0095	46
	18	0.90	<0.001	0.9420	0.0076	0.0113	39
						Average	63
						Std deviation	34
1,3-d	1	0.48*	**	1.772	0.0066	0.0288	125
	2	0.49	0.003	5.320	0.0220	0.0844	117
	3	0.94*	**	1.144	0.0097	0.0132	30
	4	0.41	0.008	0.1111	0.0003	0.0019	138
	5	0.81	<0.001	0.3712	0.0027	0.0047	55
	6	0.81	<0.001	0.6254	0.0045	0.0081	58
	7	0.56	<0.001	0.8435	0.0042	0.0127	101
	8	0.92	<0.001	2.612	0.0218	0.0304	33
	9	0.67	<0.001	1.245	0.0075	0.0174	80
	10	0.76	<0.001	1.249	0.0085	0.0165	64
	11	0.77	<0.001	5.946	0.0407	0.0783	63
	12	0.84	<0.001	2.489	0.0186	0.0312	50
	13	0.80	<0.001	5.117	0.0366	0.0658	57
	14	0.95	<0.001	5.311	0.0465	0.0598	25
	15	0.74*	**	7.780	0.0517	0.1039	67
	16	0.94	<0.001	9.432	0.0805	0.1082	29
	17	0.72	<0.001	7.208	0.0464	0.0978	71
	18	0.98	<0.001	10.79	0.0991	0.1168	16
						Average	66
						Std deviation	35

[1] percent Difference = $\frac{|C1 - C2|}{(C1 + C2)/2} * 100$

* Concentrations were sorted before regression analysis.

**p value cannot be calculated using conventional statistics.

Table 8. Difference in 24-hour TWA flux (ug/m^2/sec).

	Method of flux selection	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
MITC	Conventional	22.0	4.14	2.55	1.40	1.38	0.86
	Solar radiation	23.6	4.16	2.60	1.38	1.46	0.76
1,3-d	Conventional	1.56	1.49	4.22	5.21	8.61	9.00
	Solar radiation	1.70	1.51	4.30	5.19	9.17	7.94

Table 9. Emission, as a percent of applied material, for each daytime interval for both methods.

	MITC		1,3-d	
Sampling Interval	Conventional	Solar	Conventional	Solar
1	1.32	1.68	0.07	0.09
2	3.57	3.89	0.21	0.23
3	1.81	1.81	0.05	0.05
7	0.57	0.57	0.05	0.05
8	0.73	0.76	0.16	0.16
11	0.91	0.93	0.72	0.74
13	0.30	0.29	0.62	0.61
15	0.28	0.31	0.94	1.07
17	0.17	0.12	0.87	0.61
Total Daytime	9.65	10.36	3.67	3.61

Figure 1. Comparison of 24-hour average fluxes (ug/m^{2}s) from two different stability class methods over time and the highest and average measured 24-hour TWA concentration (ug/m^3) for any sampling site.